REMARKS

References herein to the "Specification" refer to the specification of the present application as filed on June 10, 1999.

Examiner's Interviews and Follow-Up

August 25, 2004 PTO Interview

The undersigned thanks the Examiner and Supervisory Examiner Samuel Borda for their time and assistance in providing for an in-person interview on August 25, 2004.

One item discussed during the September 25, 2004 interview was the sufficiency of the disclosure. During the interview, claim 25 was discussed as a representative claim. The undersigned presented viewgraphs showing that the elements of claim 25 are fully supported by the specification. A claim chart showing the support for the claim 25 elements was presented and the undersigned explained that Figure 10 of the specification, among others, provided significant support for the claims. A copy of that presentation is attached hereto, and excerpts of that presentation are presented below showing support for claim 25.

It is respectfully submitted that:

- Given the clear showing of support for claim 25, as presented below, there is no legal basis to suggest that claim 25 is not fully and clearly supported.

- The sufficiency of the disclosure in support of the recited claims is affirmed by the declaration of Francois Perroux (who is not an inventor of the recited claims). Francois Perroux's declaration was submitted together with the Response to Office Action Dated March 25, 2003.

August 30, 2004 Telephone call and Rejection In Light Of the Term "Free Neighborhoods"

On August 30, 2004, an additional telephone conference was held between the Examiner and the undersigned. During the August 30, 2004, telephone conference the Examiner commented that, despite the undersigned's in-person presentation providing a detailed explanation of the disclosure's teachings and claim support, the Examiner would not allow the claims. In particular, the Examiner suggested that the term "free neighborhoods" is not clear. The undersigned is puzzled as why this is not clear. As the undersigned explained both during the August 25, 2004 presentation and during the August 30, 2004, call, the term "free neighborhoods" is a term referring to the "tangent zone" and the "material zone". If the Examiner requires the undersigned to do so, and if it will provide for allowance of the claims, the undersigned will revise the specification to replace the term "free neighborhoods" with the term "tangent or material zone," thereby eliminating any confusion regarding this term. However, it is respectfully submitted that there is no legal reason for requiring the undersigned to do so, and the undersigned respectfully submits that imposing this additional burden and cost on the applicant is inappropriate without a clearly identified legal reason related to what is being claimed as the invention.

Additional Claims and Suggested Claim Amendments:

New Claim 39:

In the March 9, 2004 Office Action, and during the August 25, 2004, interview, the Examiner indicated that it is the concept of "material zone" that was not clear to the Examiner and the examiner acknowledged that the concept of "tangent zone" is understood. Claim 39 is directed to the computation of swept volume using a "tangent zone"; claim 39 does not recite the "material zone" concept. It is respectfully submitted that a useful approximations of swept volume may be obtained by the use tangent zone calculations as that concept is recited in claim 39.

New Claims 40-41:

Claims 40-42 have also been added. In the March 9, 2004 Office Action, and during the August 25, 2004, interview, the Examiner indicated that the "half-sphere" concept of "material zone" was a point of confusion. Although the undersigned believes this concept is adequately explained, the Examiner suggested that amending claim 25 to recite the concept underlying "material zone" without use of that term (or the "second zone" term). The Examiner and supervisory examiner Samuel Borda suggested that defining the "material zone" concept in terms of motion along a trajectory through the material of the object would provide sufficient clarification to the term.

In accordance with the Examiners' suggestion, claim 40 has been amended by replacing claim 25's recitation of:

> (ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:
>
> each such triangle's second zone comprises a zone represented by a half sphere,
> said half sphere comprising a flat face that is planar with said triangle, and
> said half sphere extending interior to the modeled object, and
> said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said preceding position;

With:

> (ii) determining a subset of the triangles such that, for a current position of each such triangle, motion between that current position and any subsequent or preceding position comprises motion along a trajectory directed through the interior of the modeled object;

It is believed that this amendment follows from the Examiner and supervisory Examiner's suggestions made during the August 25, 2004 interview. It is respectfully submitted that claim 40, as amended, is supported by at least the same disclosure as for the replaced text of claim 25.

Claim 41 clarifies that motion of the triangle can be approximated by analyzing any point on the surface of the triangle. Claim 41 is supported by at least the following disclosure:

> ... if one point included in the edge or the triangle entity of the boundary of the moving object is moving inside its free neighborhood [i.e., inside the tangent zone in the case of an edge or material zone in the case of a triangle], then the entire entity is moving inside its free neighborhood [i.e., inside its tangent zone or material zone].

(pages 6-7, specification as filed, text inside brackets '[]' added)

Claim 42 also follows from a clarifying suggestion made by supervisory examiner Samuel Borda. In particular, Mr. Borda suggested replacing the "half sphere" concept of "material zone" with a mathematically based description based on vectors. Claim 42 replaces claim 25's recitation of:

> (ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:
>
> each such triangle's second zone comprises a zone represented by a half sphere,
>
> said half sphere comprising a flat face that is planar with said triangle, and
>
> said half sphere extending interior to the modeled object, and
>
> said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said preceding position;

With:

> (ii) determining a subset of the triangles such that, for a current position of each such triangle, motion between that current position and any subsequent or preceding position comprises motion on a vector directed through the interior of the modeled object sand where motion of the triangle along the vector is determined at a representative point on the surface of the triangle, motion of said representative point being used to approximate motion of said triangle;

It is respectfull submitted that all pending claims are now in condition for allowance.

Exemplary Claim Support – Claim 25

During the August 25, 2004, interview, the undersigned further explained that the application disclosure, as filed, fully supports the claimed inventions. Some highlights of the presentation made on August 25, 2004, are presented below. A copy of the full presentation is attached hereto.

Page references herein refer to the specification as filed.

Claim Element:

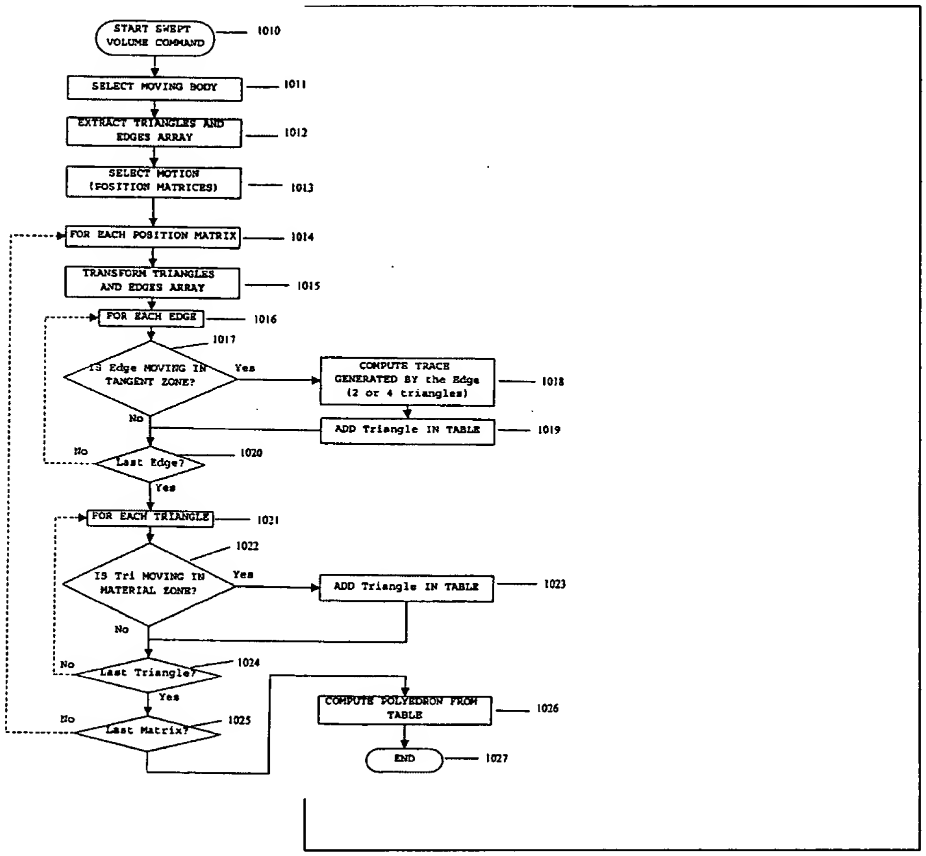
25) (Amended) A method for use in calculation of a swept volume of a computer generated model of a real-world object, the method comprising:

Support:

- "the present invention provides a method and apparatus of modeling a swept volume for a computer simulated object" (page 2)
- "To represent a swept volume the present invention can determine the boundaries of the volume, i.e., a set of surfaces (2-D entities) that close the volume. ... At a point t, a point belonging to a boundary of a moving object belongs to the boundary of its swept volume if its neighborhood with respect to the swept volume is not full, that is if the point is not inside the material of the object. ... A neighborhood of point p is not full if p remains on the boundary of the swept volume during the motion and does not enter the interior

boundary of the material. … A point moving in its free neighborhood can be equivalent to a point sliding along the surface of the material of the object modeled" (page 6)

- See, generally, Fig. 10, reproduced below:



Claim Elements:

generating a three dimensional polyhedral representation of the model of the real-world object, the representation comprising a plurality of triangles joined at their edges, said triangles forming a tessellated representation of the modeled real-world object;

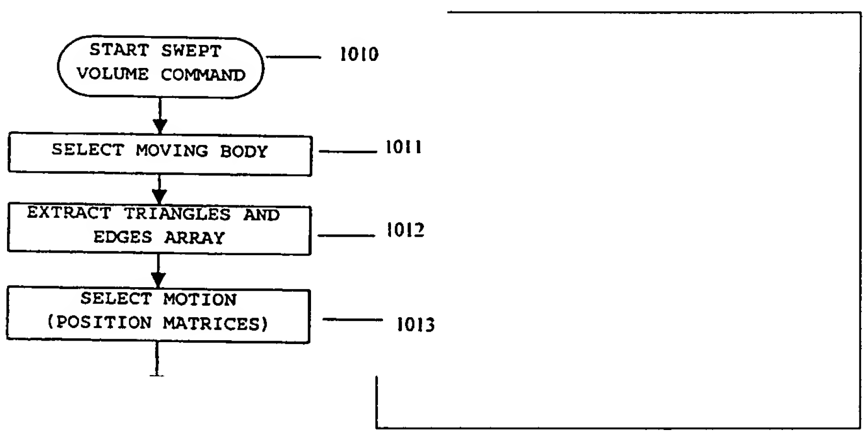
representing three dimensional motion of the modeled object by a series of sequential positions of the modeled object in three dimensional space; and

Support:

- "the invention includes generating a polyhedral representation of a computer modeled object and representing motion of the object with a set of position matrices." (page 2)

- "Referring now to Fig. 2 a computer generated model ... can include an object having a polyhedral representation, wherein the object is represented by a set of triangles. Motion of the object can be represented by an ordered set of position matrices." (page 5)

- See Fig. 10, 1010-1013



And see supporting Specification:

Referring now to Fig. 10, in one embodiment, a logical flow including the steps 1010-1027 can represent a process used to determine the swept volume generated by a motion of a polyhedral object. A "Start Swept Volume" command 1010 commencing execution of a Swept Volume program can be issued by a user or called from another program executing on a computer 100. A moving body can be selected from a computer generated model display 1011. Selection can be accomplished with a mouse or other pointing device or with an input device such as a keyboard. The program can extract an array of triangles and edges 1012. Extraction can reference stored triangle information and insert it into a diagram without modifying the information.

The motion can be selected through the selection of position matrices 1013. A

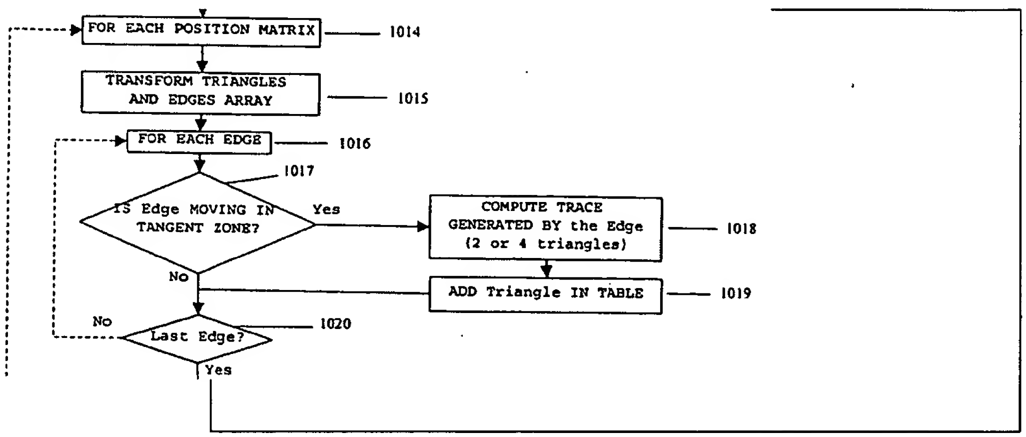
Claim Element:

for each position in the series of sequential positions of the modeled object,

(i) determining a subset of the edges such that each edge in said subset has a trajectory through a corresponding first zone in which motion of the corresponding edge comprises motion on the boundary of the modeled swept volume during motion of the modeled object from a current position to a next position,

Support:

- "A point moving in its free neighborhood can be equivalent to a point sliding along the surface of the material of the object modeled" (page 6)
- "In the case of an edge 511, a free neighborhood or material zone can be based on the normal vector 512" (page 7)(Fig. 5 shows how the normal vector relates to a material zone).
- See also, original claim 2.
- See Fig. 10, 1014, 1016-1020:



And see supporting specification:

The motion can be selected through the selection of position matrices 1013. A loop can then be set up for each position matrix 1014. The loop can call for the program to transform the triangles and edges array 1015. A sub-loop can be set up for each edge 1016. Within the edge sub-loop, a test can determine if a current edge is moving in a tangent zone 1017. If a current edge is moving in a tangent zone, the program can compute a trace generated by the edge 1018. In computing the trace generated by the edge 1018, the program can utilize two triangles to represent translation of a polygon and four triangles for motion including translation and rotation of the polygon.

Transformation of the triangles can include modifying the position of the triangles that make up a part, such as the connecting rod. A set order of positions can be defined from select motion position matrices representing the part at different instantiations. In

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the example of the connecting rod, a triangle on the edge of an array while the connecting rod is at an original position at t0 can have a position X0, Y0, and Z0. With vertical translation only, the top position of the connecting rod can be at X0, Y0, and Z1 where Z is the vertical axis. Translation can modify the position of each point of each triangle at each edge.

Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

Claim Element:

where each such edge's corresponding first zone comprising a region external to the material of the modeled object and bounded by a planar extension of the triangles that join at said edge;

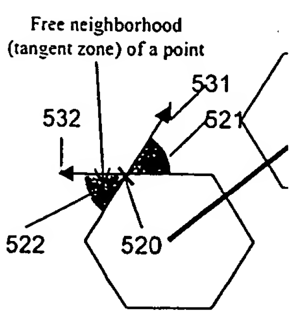
Support:

The "first zone" is supported by, *inter alia*, the application's description of a "tangent zone"

- "Two types of free neighborhood can be utilized in a swept volume computation. ... The free neighborhood of an edge can be delimited by two portions of a sphere delimited by the planes of the adjacent triangles. This type of neighborhood can be referred to as a tangent zone." (page 7)

- "In the case of an edge, represented in 2-D by a point 520, the free neighborhood can be represented by two portions of sphere 521 and 522. The spheres can be delimited by planes of adjacent triangles 531 and 532. The free neighborhood of an edge 521 and 522 can be referred to as a tangent zone." (page 7)

- See Fig. 5 "(tangent zone)"



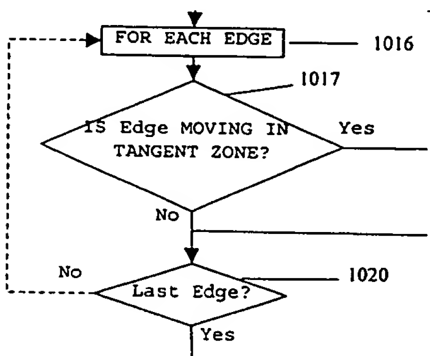
And supporting specification:

The half sphere 510 can be referred to as a material zone. In the case of an edge, represented in 2-D by a point 520, the free neighborhood can be represented by two portions of a sphere 521 and 522. The spheres can be delimited by the planes of adjacent triangles 531 and 532. The free neighborhood of an edge 521 and 522 can be referred to as a tangent zone.

- See also, original claim 6.

6) The software control method of claim 4 wherein the free neighbor hood comprises a tangent zone represented by two portions of a sphere, wherein the two portions of the sphere are delimited by planes of adjacent triangles.

- See Also Fig. 10, element 1017



Claim Element:

(ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:

each such triangle's second zone comprises a zone represented by a half sphere, said half sphere comprising a flat face that is planar with said triangle, and said half sphere extending interior to the modeled object, and

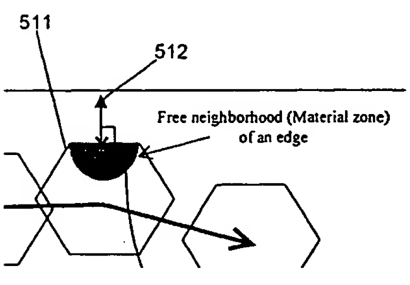
said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said preceding position;

Support:

The "second zone" is supported by, *inter alia*, the application's description of a "material zone." See, e.g.:

- "Two types of free neighborhood can be utilized in a swept volume computation. The free neighborhood of a triangle can be represented with a half-sphere containing material and delimited by the plane of the triangle. This type of free neighborhood can be referred to as the material zone." (page 7)

- See Fig. 5 – "(material zone")



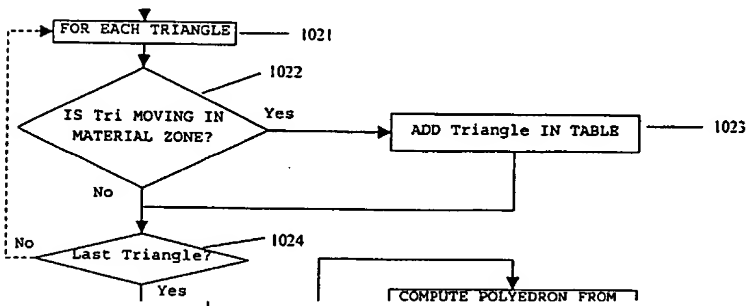
And see:

Two types of free neighborhood can be utilized in a swept volume computation. The free neighborhood of a triangle can be represented with a half-sphere containing material and delimited by the plane of the triangle. This type of free neighborhood can be referred to as the material zone.

- See also, claim 5 as filed:.

5) The software control method of claim 4 wherein a free neighborhood comprises a material zone represented by a half sphere containing material of object and delimited by a plane of a triangle.

- And see Fig. 10, elements 1021-1024:



And see supporting specification:

A loop for each triangle 1021 can also process. The logical order of the loops is not significant. A loop for triangles can precede a loop for edges, or an edge loop may precede a triangle loop. The loop for each triangle can test for movement of a triangle in a material zone 1022. A triangle moving through a material zone can be added to the table used to compute a polyhedron 1023. The loop for each triangle can continue until the last triangle has been tested 1024.

Claim Element:

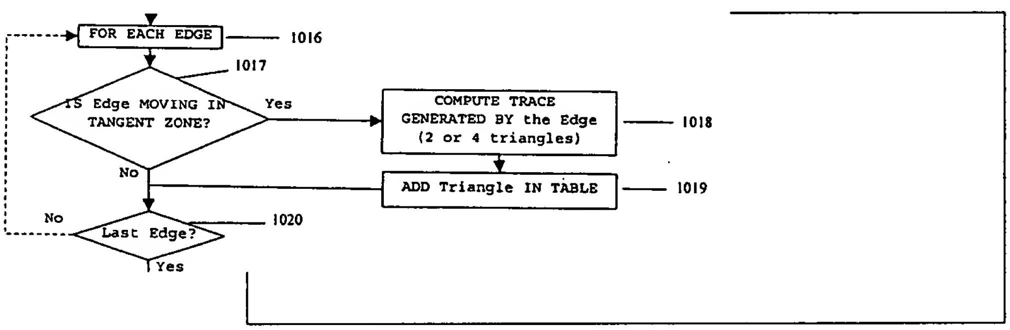
(iii) generating a trace of the motion of said subset of edges between said current and said next positions; and

constructing a representation of the swept volume from the generated traces of the motion of said subset of edges;

Support:

- "A boundary of a swept volume can generally be modeled by determining for each time t a subset of points belonging to the boundary of the moving object and sliding along the boundary of the swept volume. This determination can be based on a study of the free neighborhood of the point. A trace can be computed and generated by the motion of the point. The swept volume can be constructed from representation from multiple traces." (page 6)

- And see Fig. 10, element 1018-1019.



And supporting specification:

to transform the triangles and edges array 1015. A sub-loop can be set up for each edge 1016. Within the edge sub-loop, a test can determine if a current edge is moving in a tangent zone 1017. If a current edge is moving in a tangent zone, the program can compute a trace generated by the edge 1018. In computing the trace generated by the edge 1018, the program can utilize two triangles to represent translation of a polygon and four triangles for motion including translation and rotation of the polygon.

Transformation of the triangles can include modifying the position of the triangles that make up a part, such as the connecting rod. A set order of positions can be defined from select motion position matrices representing the part at different instantiations. In

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the example of the connecting rod, a triangle on the edge of an array while the connecting rod is at an original position at t0 can have a position X0, Y0, and Z0. With vertical translation only, the top position of the connecting rod can be at X0, Y0, and Z1 where Z is the vertical axis. Translation can modify the position of each point of each triangle at each edge.

Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

Claim Element:

wherein constructing a representation of the swept volume further comprises bounding the swept volume at each of said current positions in said series by said subset of triangles associated with each such current position.

Support:

- "A boundary of a swept volume can generally be modeled by determining for each time t a subset of points belonging to the boundary of the moving object and sliding along the boundary of the swept volume. This determination can be based on a study of the free neighborhood of the point. A trace can be computed and generated by the motion of the point. The swept volume can be constructed from representation from multiple traces." (page 6)

- See Figs. 8, 9, 10 element 1023, 1026.

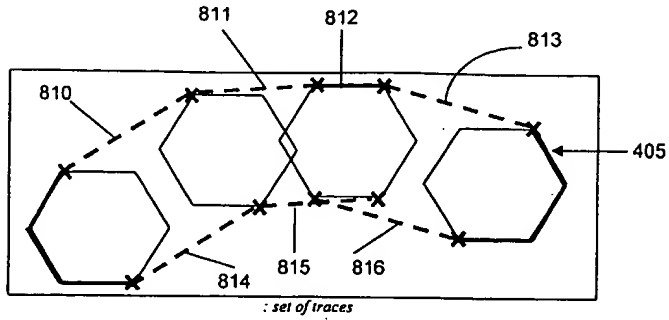


Fig. 8

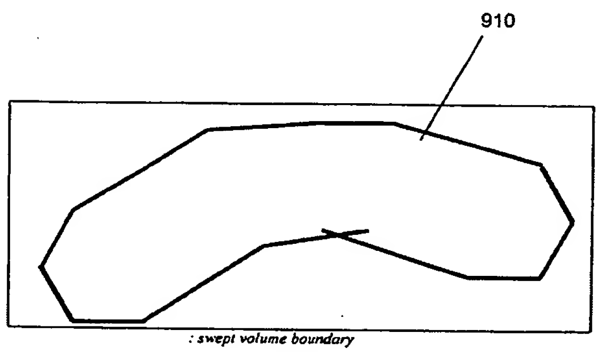


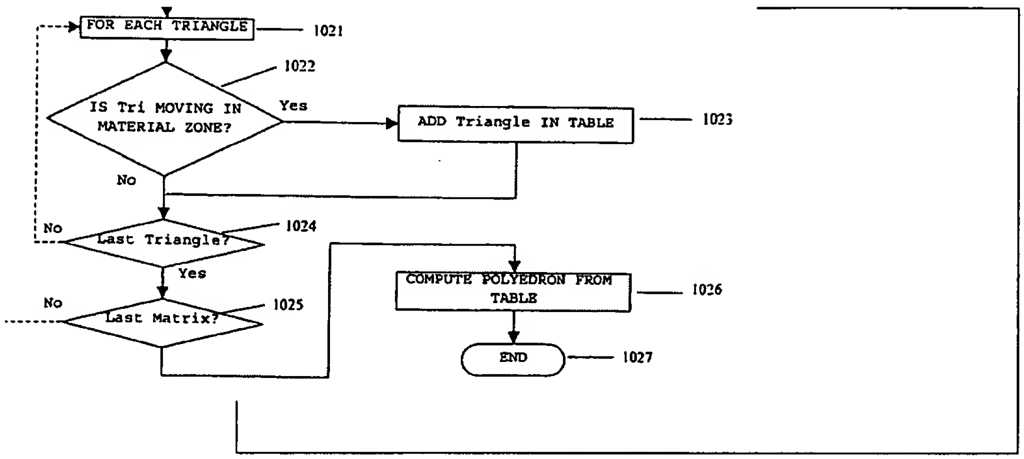
Fig. 9

And supporting specification:

FIG. 8 illustrates tracking translation of a polygon.

FIG. 9 illustrates forming a swept volume boundary from the translation of Fig. 8.

And See Fig. 10:



And see supporting specification:

Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

A loop for each triangle 1021 can also process. The logical order of the loops is not significant. A loop for triangles can precede a loop for edges, or an edge loop may precede a triangle loop. The loop for each triangle can test for movement of a triangle in a material zone 1022. A triangle moving through a material zone can be added to the table used to compute a polyhedron 1023. The loop for each triangle can continue until the last triangle has been tested 1024.

The matrix loop can continue to transform a triangles and edges array and run edge and triangle sub-loops for each matrix until a last matrix is reached 1025. When all matrices have been processed, the program can compute a polyhedron from information contained in a table into which the triangles have been stored 1026. Finally, a swept volume command program can come to an end 1027.

FURTHER REMARKS IN RESPONSE TO OFFICE ACTION DATED MARCH 9, 2004

The undersigned's Remarks are preceded by related comments of the Examiner, presented in small bold-faced type.

Claim Rejections - 35 USC § 112

The Examiner's rejection of claims under 35 USC § 112 appears to have been based on confusion regarding the use of a half-sphere and/or other "material zone" related concepts.

During the PTO interview on August 25, 2004, the undersigned provided a presentation explaining these concepts. A copy of that presentation is attached hereto and relevant sections explaining claim 25 and its related disclosure are presented above. The undersigned believes that, during the undersigned's presentation, it was shown that these concepts can be understood from the specification. The clarity of disclosure is further supported by the previously-provided affidavit of Francois Perroux.

> **7.6 Applicants are encouraged to attempt to clear the questions regarding the viability of a second zone comprising a half sphere and a half circle, by appearing for a personal interview at the U.S. Patent and Trademark Office with some type of demonstration of the swept volume that they are claiming.**

An in-person interview was held on August 25, 2004. The undersigned thanks the Examiner and supervisory Examiner Samuel Borda for their time and for helpful suggestions made during the interview.

Conclusion

Claims 39-42 have been added. Claims 25, 28, 30, 31, 33, 35, 36, and 38-42 are now pending.

It is respectfully submitted that:

- Given the clear showing of support for claim 25, as presented above, there is no legal basis to suggest that claim 25 is not fully and clearly supported.

- The sufficiency of the disclosure in support of the recited claims is affirmed by the declaration of Francois Perroux (who is not an inventor of the recited claimjs). Francois Perroux's declaration was submitted together with the Response to Office Action Dated March 25, 2003.

Accordingly, it is respectfully submitted that all pending claims are in condition for allowance and fully supported by the specification. Applicants respectfully requests that all pending claims be allowed.

Please apply any credits or excess charges to our deposit account number 50-0521.

Respectfully submitted,

Date: Sept 8, 2004

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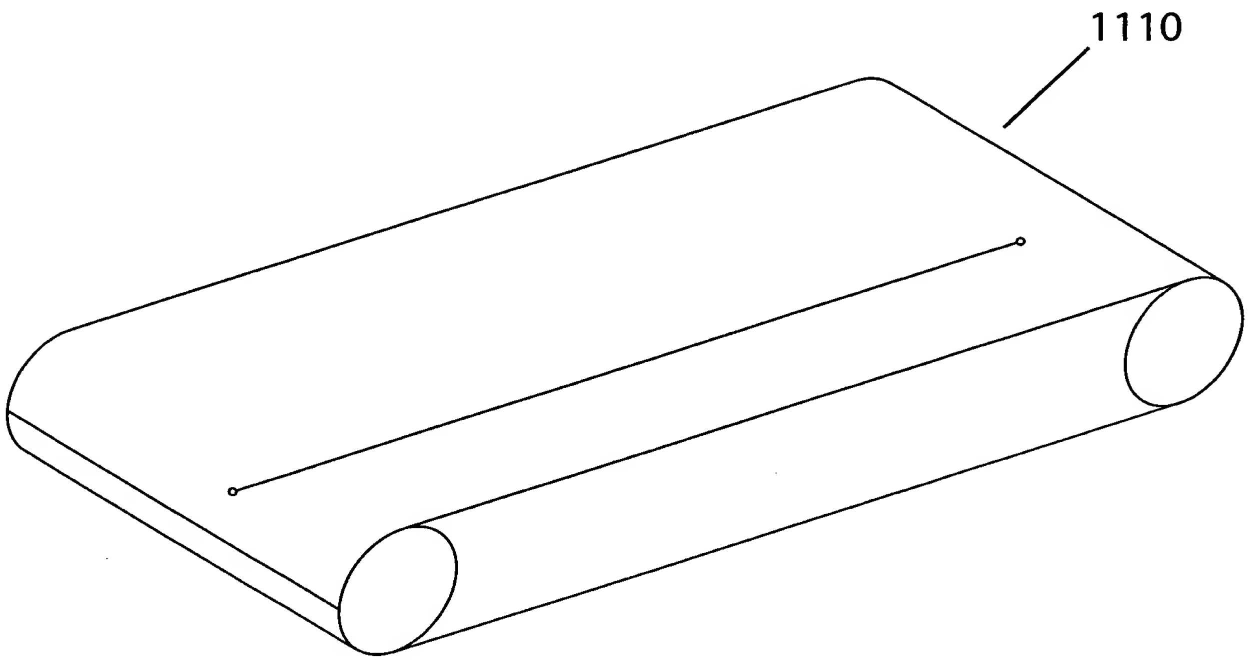

FIG. 11

No changes made - clearer copy of drawing

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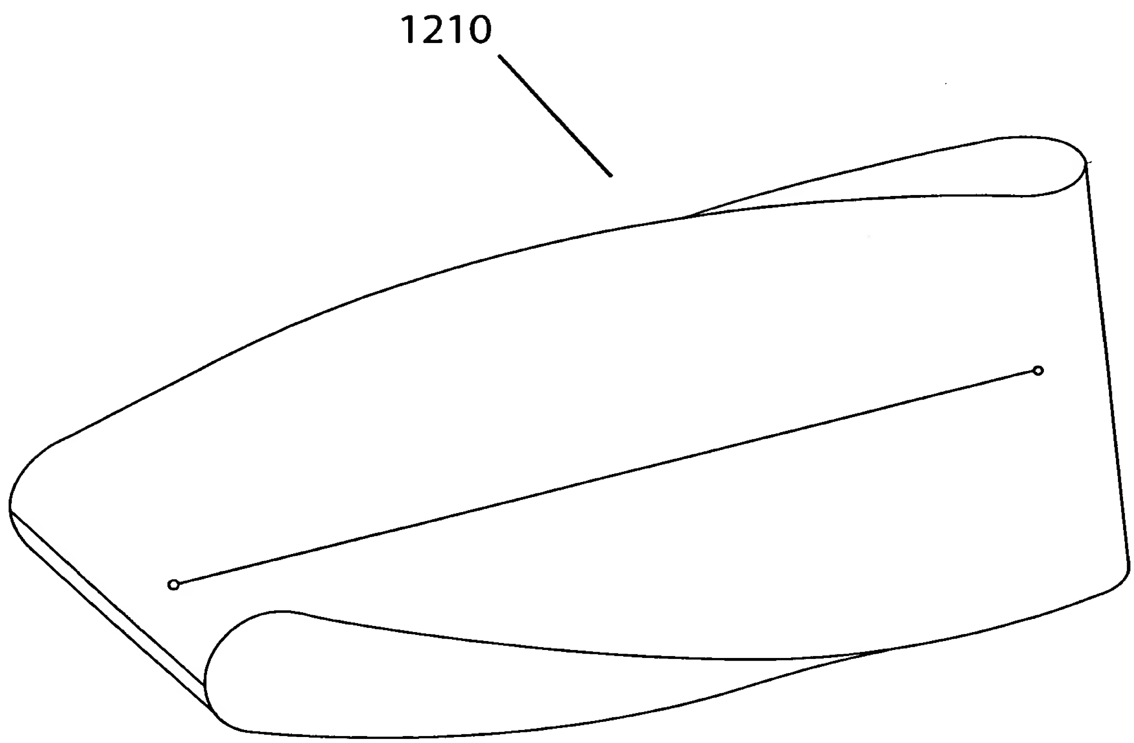

FIG. 12

No changes made - clearer copy of drawing

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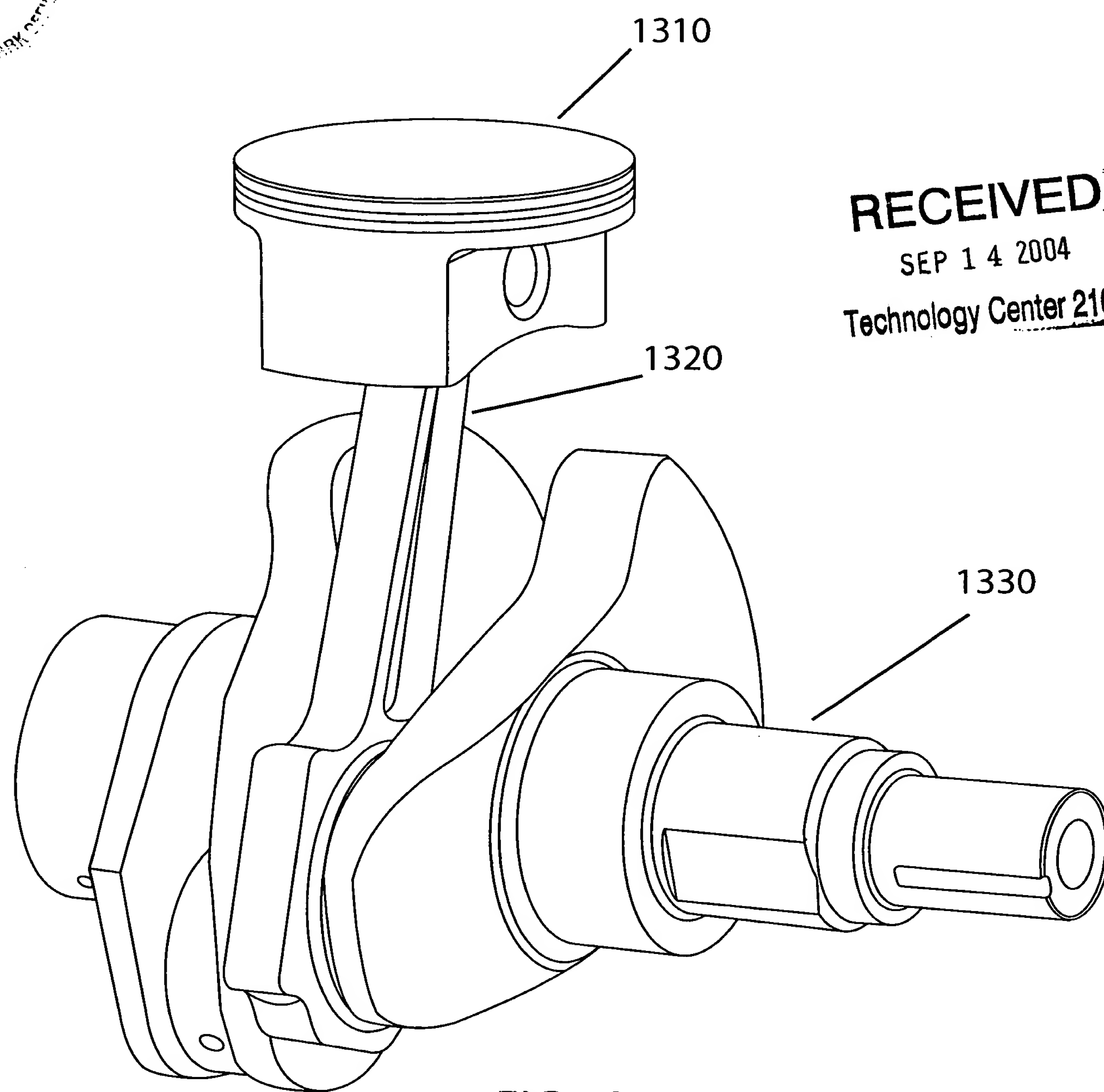

FIG. 13

Drawing now shown in a rotated view

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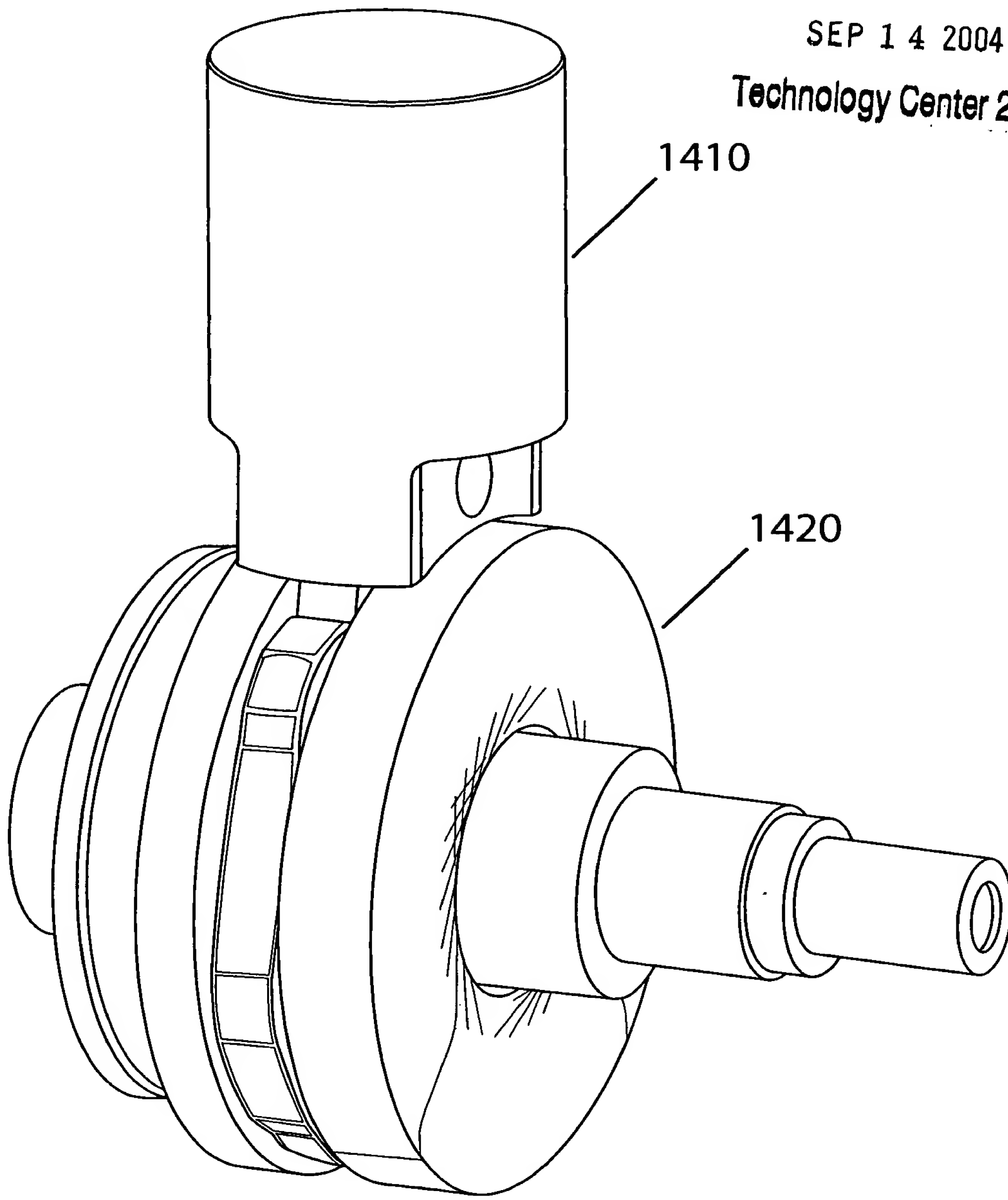

FIG. 14

Drawing now shown in a rotated view

AUGUST 25, 2004
USPTO PRESENTATION

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Swept Volume Model

Presentation to the USPTO
August 25, 2004

Request by USPTO

- "7.6 Applicants are encouraged to attempt to clear the question regarding the viability of a second zone comprising a half sphere and a half circle, by appearing for a personal interview at the U.S. Patent and Trademark Office with some type of demonstration of the swept volume that they are claiming"
- (Office Action dated March 9, 2004)

Overview

- The Invention
- Prior Art
- Example Walk-throughs
- Supporting Disclosure
  - Terminology
  - Claim elements (claim 25)

Field of the Invention

- “The present invention relates to computer software utility programs, and more specifically to a machine and method for producing a swept volume model in computer aided design and computer aided manufacturing (CAD/CAM) software systems” (page 1)

Video Example

Swept Volume of object undergoing translational motion

Background

- Prior art disclosed techniques to compute a swept volume. Page 1 of present application identifies several prior art techniques:
  - Multi-instantiation of a moving object
    - Straight-line and Boolean
  - Voxel representation of a swept volume
  - Marching cubes algorithm

Key Concepts

- Free Neighborhoods:
  - Tangent Zone
  - Material Zone
- Swept Volume computed based on entities (e.g., edges, triangles) moving in their "free neighborhoods"
  - "To represent a swept volume the present invention can determine the boundaries of the volume, i.e., a set of surfaces (2-D entities) that close the volume. ... At a point t, a point belonging to a boundary of a moving object belongs to the boundary of its swept volume if its neighborhood with respect to the swept volume is not full, that is if the point is not inside the material of the object. ... A neighborhood of point p is not full if p remains on the boundary of the swept volume during the motion and does not enter the interior boundary of the material. ... A point moving in its free neighborhood can be equivalent to a point sliding along the surface of the material of the object modeled" (page 6)

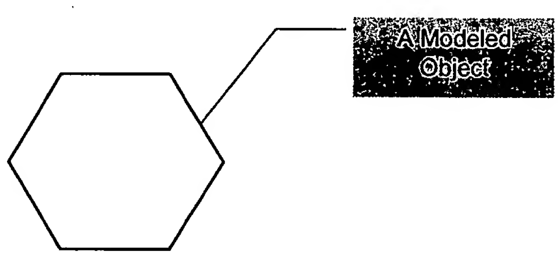


Fig. 5

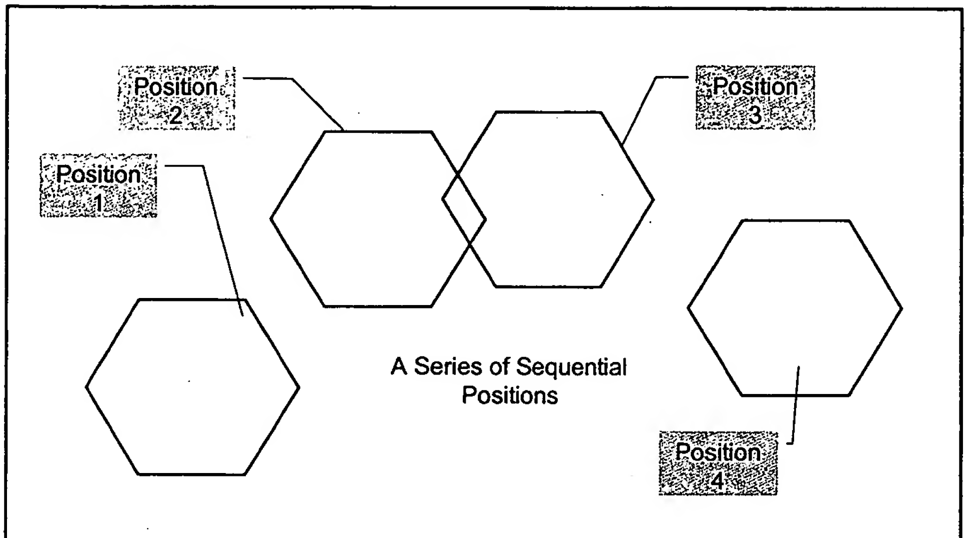
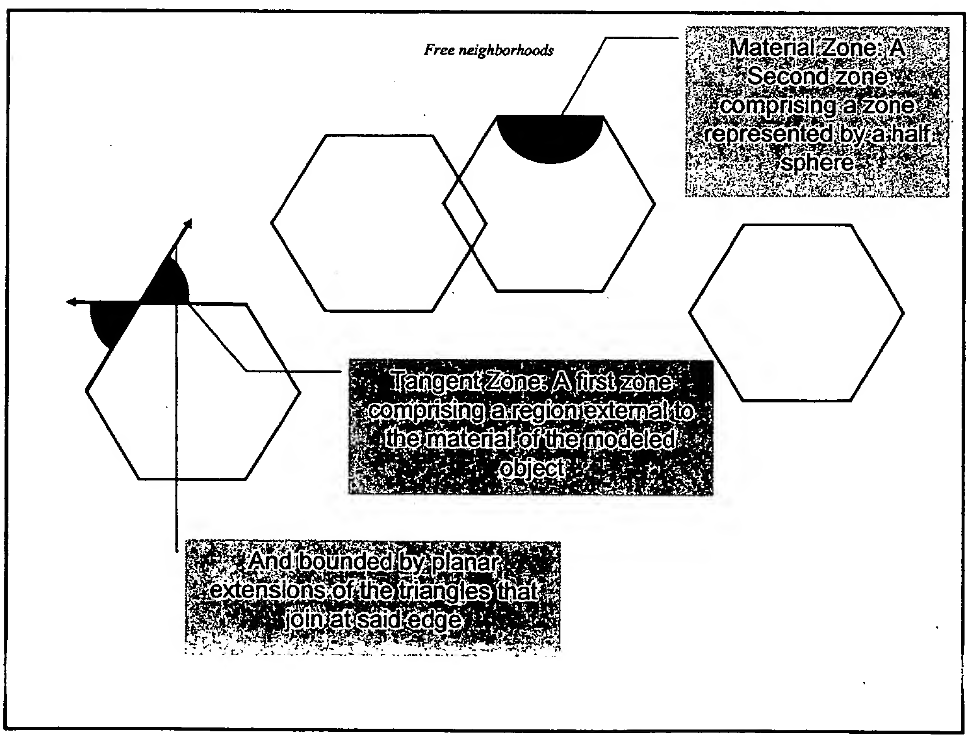

Position 2
Position 3
Position 1
A Series of Sequential Positions
Position 4

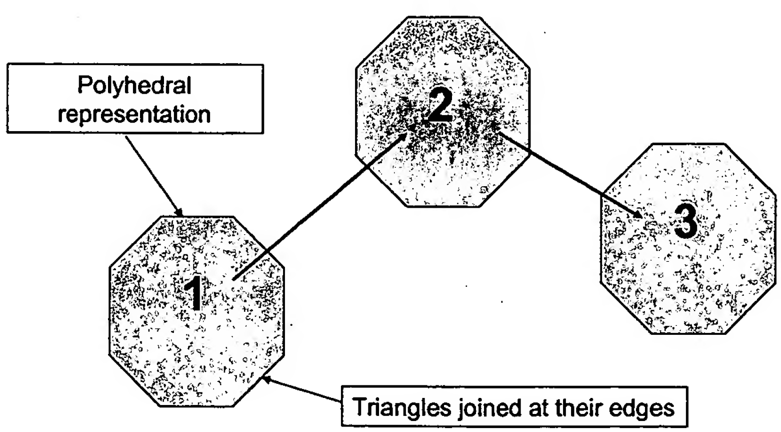
Fig. 5


Free neighborhoods
Material Zone: A Second zone comprising a zone represented by a half sphere
Tangent Zone: A first zone comprising a region external to the material of the modeled object
And bounded by planar extensions of the triangles that join at said edge

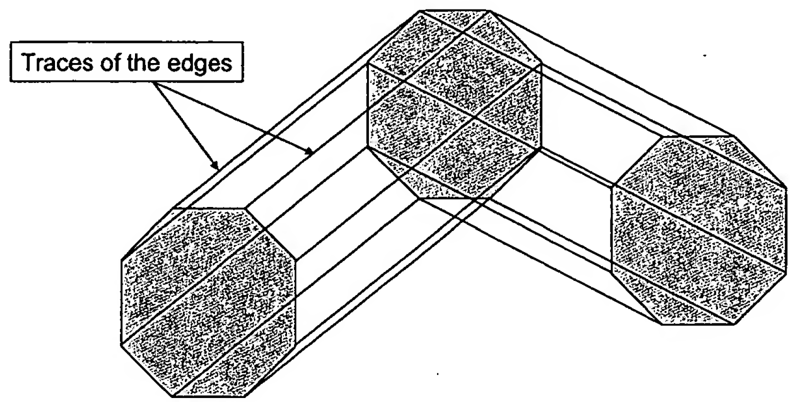
Example Walk-Throughs

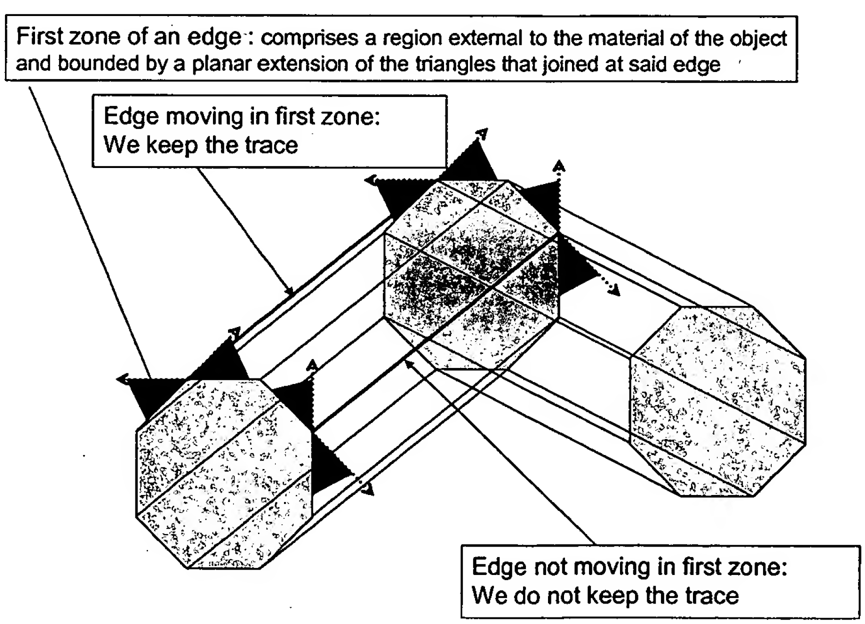
- Swept volume of object undergoing translational motion
- Swept volume of object undergoing rotational motion

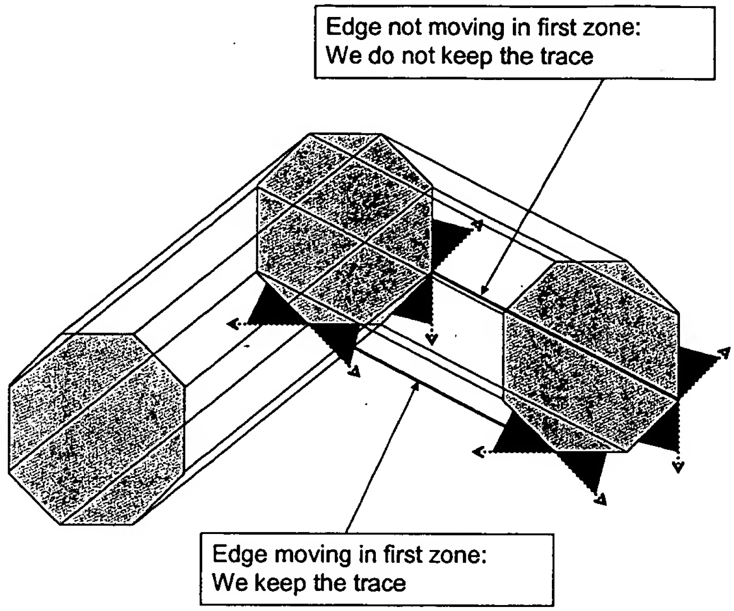
First example, translation



Selection of edges and their traces in first zone



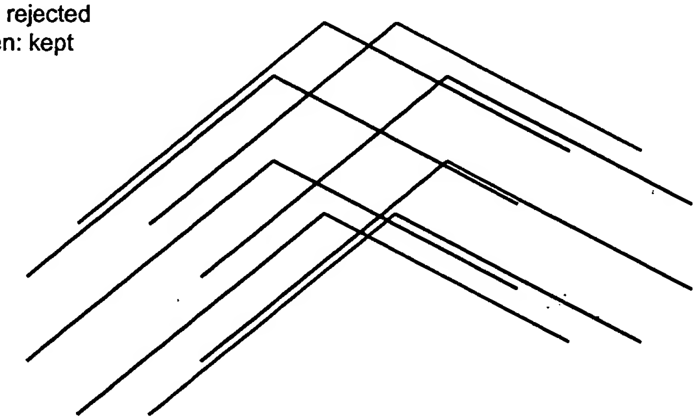




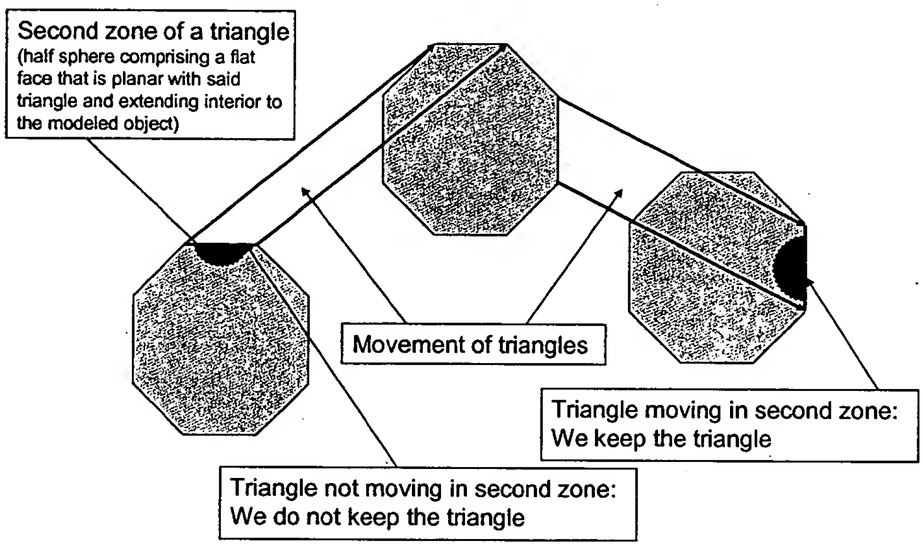
Resulting set of kept traces

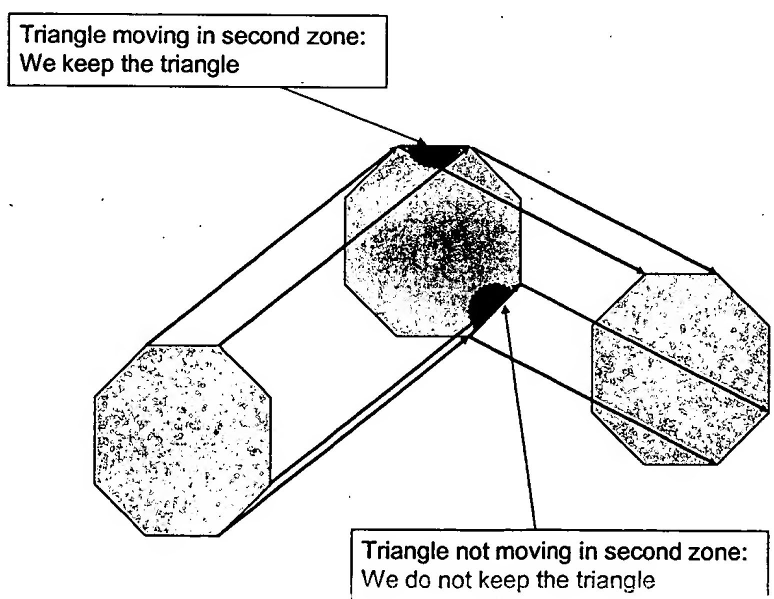
In green, generated traces of the motion of the subset of edges

Red: rejected
Green: kept



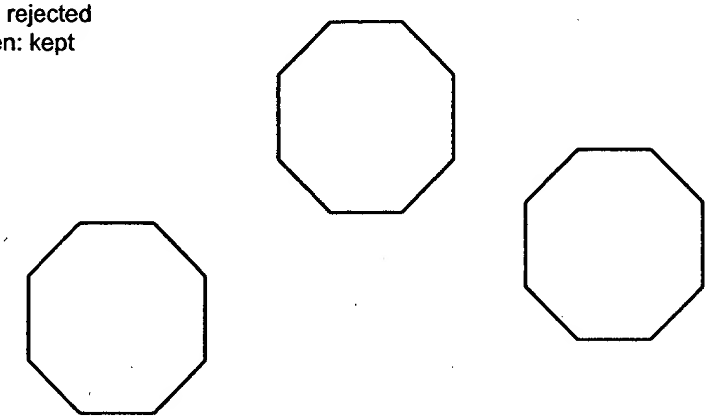
Selection of triangles moving in second zone





Resulting set of kept triangles

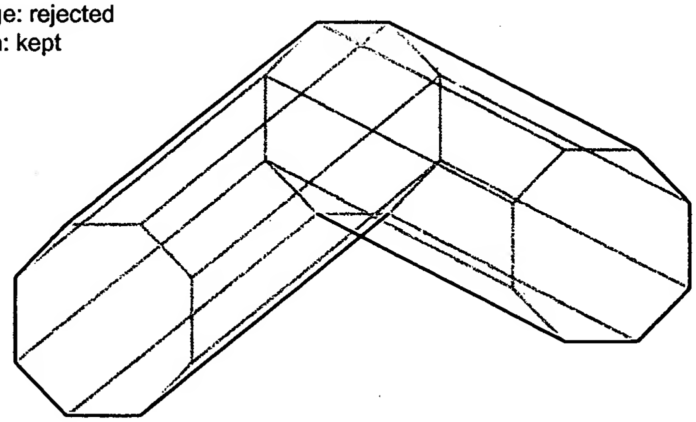
Red: rejected
Green: kept



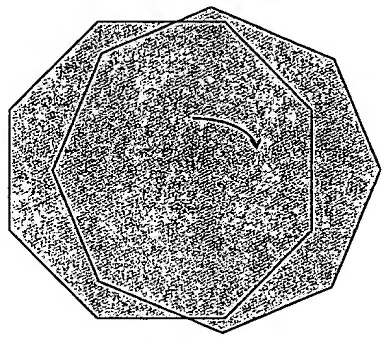
Resulting swept volume

Constructed from the generated traces of the motion of the subset of edges bounded by the subset of triangles

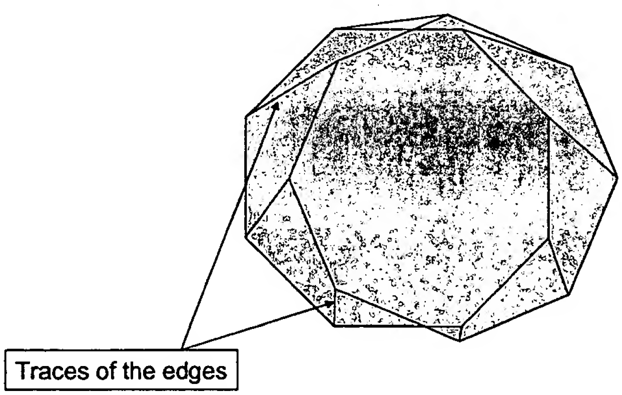
Orange: rejected
Green: kept

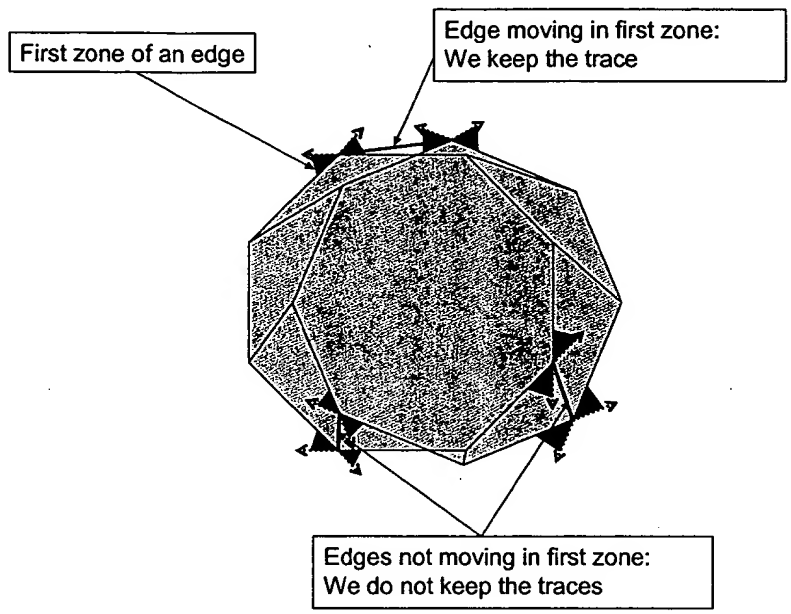


Second example, rotation



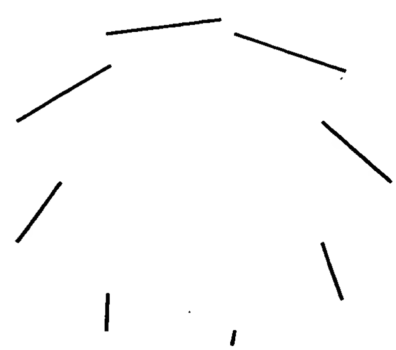
Selection of edges and their traces in first zone



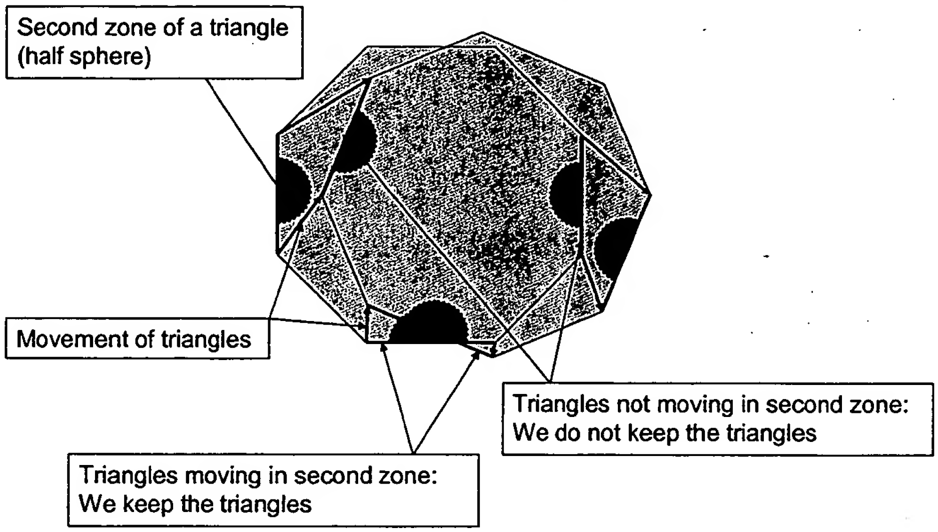


Resulting set of kept traces

Red: rejected
Green: kept

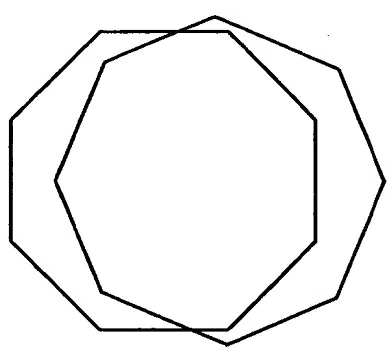


Selection of triangles moving in second zone



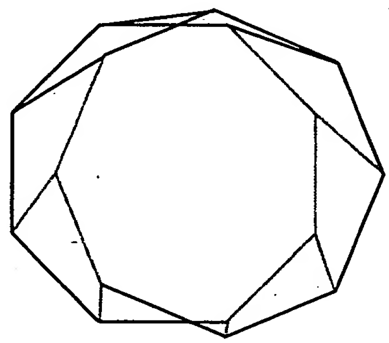
Resulting set of kept triangles

Red: rejected
Green: kept



Resulting swept volume

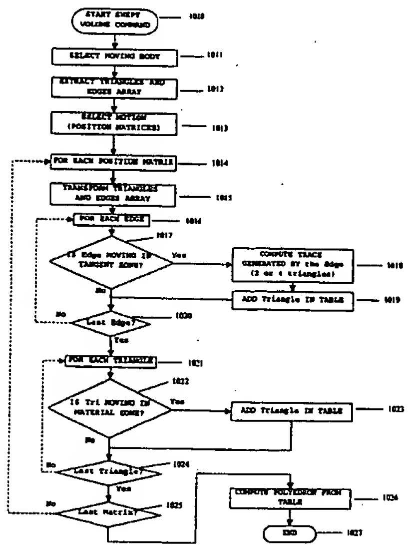
Orange: rejected
Green: kept



Pending Claim 25

- 25) (Amended) A method for use in calculation of a swept volume of a computer generated model of a real-world object, the method comprising:
- generating a three dimensional polyhedral representation of the model of the real-world object, the representation comprising a plurality of triangles joined at their edges, said triangles forming a tessellated representation of the modeled real-world object;
- representing three dimensional motion of the modeled object by a series of sequential positions of the modeled object in three dimensional space; and
- for each position in the series of sequential positions of the modeled object,
  - (i) determining a subset of the edges such that each edge in said subset has a trajectory through a corresponding first zone in which motion of the corresponding edge comprises motion on the boundary of the modeled swept volume during motion of the modeled object from a current position to a next position, where each such edge's corresponding first zone comprising a region external to the material of the modeled object and bounded by a planar extension of the triangles that join at said edge;
  - (ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:
    - each such triangle's second zone comprises a zone represented by a half sphere,
    - said half sphere comprising a flat face that is planar with said triangle, and
    - said half sphere extending interior to the modeled object, and
    - said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said preceding position;
  - (iii) generating a trace of the motion of said subset of edges between said current and said next positions; and
- constructing a representation of the swept volume from the generated traces of the motion of said subset of edges
- wherein constructing a representation of the swept volume further comprises bounding the swept volume at each of said current positions in said series by said subset of triangles associated with each such current position.

Fig. 10

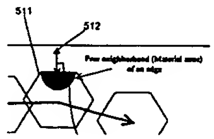


Proposed Claim 25

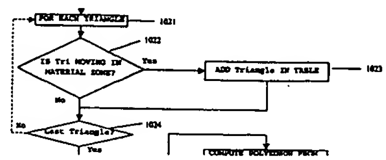
- 25) (Amended) A method for use in calculation of a swept volume of a computer generated model of a real-world object, the method comprising:
- generating a three dimensional polyhedral representation of the model of the real-world object, the representation comprising a plurality of triangles joined at their edges, said triangles forming a tessellated representation of the modeled real-world object;
- representing three dimensional motion of the modeled object by a series of sequential positions of the modeled object in three dimensional space; and
- for each position in the series of sequential positions of the modeled object,
  - (i) determining a subset of the edges such that each edge in said subset has a trajectory through a corresponding first zone in which motion of the corresponding edge comprises motion on the boundary of the modeled swept volume during motion of the modeled object from a current position to a next position, where each such edge's corresponding first zone comprising a region external to the material of the modeled object and bounded by a planar extension of the triangles that join at said edge;
  - (ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:
    - each such triangle's second zone comprises a zone represented by a half sphere,
    - said half sphere comprising a flat face that is planar with said triangle, and
    - said half sphere extending interior to the modeled object [, and
    - [said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said [preceding] current position];
  - (iii) generating a trace of the motion of said subset of edges between said current and said next positions; and
- constructing a representation of the swept volume from the generated traces of the motion of said subset of edges;
- wherein constructing a representation of the swept volume further comprises bounding the swept volume at each of said current positions in said series by said subset of triangles associated with each such current position.

Claim 25 – Claim Elements and Representative Disclosure (cont.)

Two types of free neighborhood can be utilized in a swept volume computation. The free neighborhood of a triangle can be represented with a half-sphere containing material and delimited by the plane of the triangle. This type of free neighborhood can be referred to as the material zone.



A loop for each triangle 1021 can also process. The logical order of the loops is not significant. A loop for triangles can precede a loop for edges, or an edge loop may precede a triangle loop. The loop for each triangle can test for movement of a triangle in a material zone 1022. A triangle moving through a material zone can be added to the table used to compute a polyhedron 1023. The loop for each triangle can continue until the last triangle has been tested 1024.



Claim 25 – Claim Elements and Representative Disclosure (cont.)

[, and

[said second zone representing a space that had been occupied by at least a portion of the modeled object when the modeled object was positioned at said [preceding] <u>current</u> position]

- See Figs. 5, 7

Claim 25 – Claim Elements and Representative Disclosure

25) (Amended) A method for use in calculation of a swept volume of a computer generated model of a real-world object, the method comprising:

- "the present invention provides a method and apparatus of modeling a swept volume for a computer simulated object" (page 2)
- "To represent a swept volume the present invention can determine the boundaries of the volume, i.e., a set of surfaces (2-D entities) that close the volume. ... At a point t, a point belonging to a boundary of a moving object belongs to the boundary of its swept volume if its neighborhood with respect to the swept volume is not full, that is if the point is not inside the material of the object. ... A neighborhood of point p is not full if p remains on the boundary of the swept volume during the motion and does not enter the interior boundary of the material. ... A point moving in its free neighborhood can be equivalent to a point sliding along the surface of the material of the object modeled" (page 6)
- See, generally, Fig. 10.

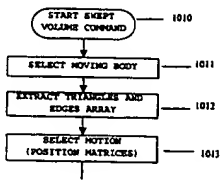
Claim 25 – Claim Elements and Representative Disclosure (cont.)

generating a three dimensional polyhedral representation of the model of the real-world object, the representation comprising a plurality of triangles joined at their edges, said triangles forming a tessellated representation of the modeled real-world object;

representing three dimensional motion of the modeled object by a series of sequential positions of the modeled object in three dimensional space; and

- "the invention includes generating a polyhedral representation of a computer modeled object and representing motion of the object with a set of position matrices." (page 2)
- "Referring now to Fig. 2 a computer generated model ... can include an object having a polyhedral representation, wherein the object is represented by a set of triangles. Motion of the object can be represented by an ordered set of position matrices." (page 5)
- See Fig. 10, 1010-1013

Claim 25 – Claim Elements and Representative Disclosure (cont.)



Referring now to Fig. 10, in one embodiment, a logical flow including the steps 1010-1027 can represent a process used to determine the swept volume generated by a motion of a polyhedral object. A "Start Swept Volume" command 1010 commencing execution of a Swept Volume program can be issued by a user or called from another program executing on a computer 100. A moving body can be selected from a computer generated model display 1011. Selection can be accomplished with a mouse or other pointing device or with an input device such as a keyboard. The program can extract an array of triangles and edges 1012. Extraction can reference stored triangle information and insert it into a diagram without modifying the information.

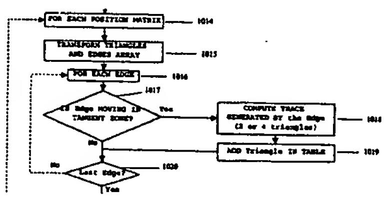
The motion can be selected through the selection of position matrices 1013. A

Claim 25 – Claim Elements and Representative Disclosure (cont.)

for each position in the series of sequential positions of the modeled object,
(i) determining a subset of the edges such that each edge in said subset has a trajectory through a corresponding first zone in which motion of the corresponding edge comprises motion on the boundary of the modeled swept volume during motion of the modeled object from a current position to a next position,

- "A point moving in its free neighborhood can be equivalent to a point sliding along the surface of the material of the object modeled" (page 6)
- "In the case of an edge 511, a free neighborhood or material zone can be based on the normal vector 512" (page 7)(Fig. 5 shows how the normal vector relates to a material zone).
- See also, original claim 2.
- See Fig. 10, 1014, 1016-1020

Claim 25 – Claim Elements and Representative Disclosure (cont.)



The motion can be selected through the selection of position matrices 1013. A loop can then be set up for each position matrix 1014. The loop can call for the program to transform the triangles and edges array 1015. A sub-loop can be set up for each edge 1016. Within the edge sub-loop, a test can determine if a current edge is moving in a tangent zone 1017. If a current edge is moving in a tangent zone, the program can compute a trace generated by the edge 1018. In computing the trace generated by the edge 1018, the program can utilize two triangles to represent translation of a polygon and four triangles for motion including translation and rotation of the polygon.

Transformation of the triangles can include modifying the position of the triangles that make up a part, such as the connecting rod. A set order of positions can be defined from select motion position matrices representing the part at different instantiations. In

8

the example of the connecting rod, a triangle on the edge of an array while the connecting rod is at an original position at t0 can have a position X0, Y0, and Z0. With vertical translation only, the top position of the connecting rod can be at X0, Y0, and Z1 where Z is the vertical axis. Translation can modify the position of each point of each triangle at each edge.

Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

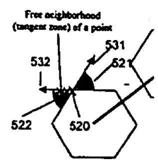
Claim 25 – Claim Elements and Representative Disclosure (cont.)

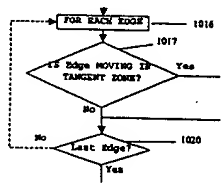
where each such edge's corresponding first zone comprising a region external to the material of the modeled object and bounded by a planar extension of the triangles that join at said edge;

- "first zone" is a "tangent zone".
- "Two types of free neighborhood can be utilized in a swept volume computation. ... The free neighborhood of an edge can be delimited by two portions of a sphere delimited by the planes of the adjacent triangles. This type of neighborhood can be referred to as a tangent zone." (page 7)
- "In the case of an edge, represented in 2-D by a point 520, the free neighborhood can be represented by two portions of sphere 521 and 522. The spheres can be delimited by planes of adjacent triangles 531 and 532. The free neighborhood of an edge 521 and 522 can be referred to as a tangent zone." (page 7)
- See Fig. 5 "(tangent zone)"
- See also, original claim 6.
- See Fig. 10, element 1017

Claim 25 – Claim Elements and Representative Disclosure (cont.)

The half sphere 510 can be referred to as a material zone. In the case of an edge, represented in 2-D by a point 520, the free neighborhood can be represented by two portions of a sphere 521 and 522. The spheres can be delimited by the planes of adjacent triangles 531 and 532. The free neighborhood of an edge 521 and 522 can be referred to as a tangent zone.





6) The software control method of claim 4 wherein the free neighbor hood comprises a tangent zone represented by two portions of a sphere, wherein the two portions of the sphere are delimited by planes of adjacent triangles.

Claim 25 – Claim Elements and Representative Disclosure (cont.)

(ii) determining a subset of the triangles such that each triangle in said subset has a trajectory through a corresponding second zone during motion of the modeled object from a preceding position to a current position and from the current position to a next position; and where:

each such triangle's second zone comprises a zone represented by a half sphere, said half sphere comprising a flat face that is planar with said triangle, and said half sphere extending interior to the modeled object;

- The "second zone" is a "material zone"
- "Two types of free neighborhood can be utilized in a swept volume computation. The free neighborhood of a triangle can be represented with a half-sphere containing material and delimited by the plane of the triangle. This type of free neighborhood can be referred to as the material zone." (page 7)
- See Fig. 5 – "(material zone")
- See also, original claim 5.
- See Fig. 10, elements 1021-1024

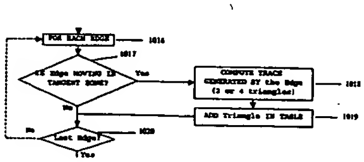
Claim 25 – Claim Elements and Representative Disclosure (cont.)

(iii) generating a trace of the motion of said subset of edges between said current and said next positions; and

constructing a representation of the swept volume from the generated traces of the motion of said subset of edges;

- "A boundary of a swept volume can generally be modeled by determining for each time t a subset of points belonging to the boundary of the moving object and sliding along the boundary of the swept volume. This determination can be based on a study of the free neighborhood of the point. A trace can be computed and generated by the motion of the point. The swept volume can be constructed from representation from multiple traces." (page 6)
- See Fig. 10, element 1018-1019.

Claim 25 – Claim Elements and Representative Disclosure (cont.)



to transform the triangles and edges array 1015. A sub-loop can be set up for each edge 1016. Within the edge sub-loop, a test can determine if a current edge is moving in a tangent zone 1017. If a current edge is moving in a tangent zone, the program can compute a trace generated by the edge 1018. In computing the trace generated by the edge 1018, the program can utilize two triangles to represent translation of a polygon and four triangles for motion including translation and rotation of the polygon.

Transformation of the triangles can include modifying the position of the triangles that make up a part, such as the connecting rod. A set order of positions can be defined from select motion position matrices representing the part at different instantiations. In

8

the example of the connecting rod, a triangle on the edge of an array while the connecting rod is at an original position at t0 can have a position X0, Y0, and Z0. With vertical translation only, the top position of the connecting rod can be at X0, Y0, and Z1 where Z is the vertical axis. Translation can modify the position of each point of each triangle at each edge.

Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

Claim 25 – Claim Elements and Representative Disclosure (cont.)

wherein constructing a representation of the swept volume further comprises bounding the swept volume at each of said current positions in said series by said subset of triangles associated with each such current position.

- "A boundary of a swept volume can generally be modeled by determining for each time t a subset of points belonging to the boundary of the moving object and sliding along the boundary of the swept volume. This determination can be based on a study of the free neighborhood of the point. A trace can be computed and generated by the motion of the point. The swept volume can be constructed from representation from multiple traces." (page 6)
- See Figs. 8, 9, 10 element 1023, 1026.

Claim 25 – Claim Elements and Representative Disclosure (cont.)

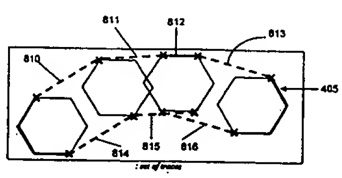


Fig. 8

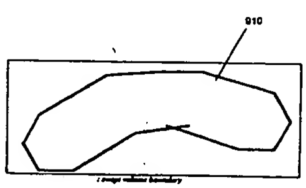
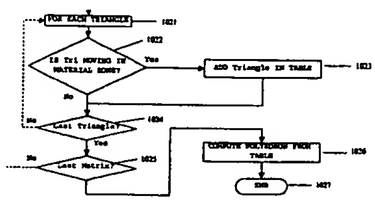


Fig. 9

FIG. 8 illustrates tracking translation of a polygon.

FIG. 9 illustrates forming a swept volume boundary from the translation of Fig. 8.

Claim 25 – Claim Elements and Representative Disclosure (cont.)



Following computation of a trace generated by the edge 1018, the program can add the triangle to a table 1019. Triangles stored in the table can later be referenced to model a polyhedron representation of the swept volume. The loop can continue for each edge until a last edge has been computed 1020.

A loop for each triangle 1021 can also process. The logical order of the loops is not significant. A loop for triangles can precede a loop for edges, or an edge loop may precede a triangle loop. The loop for each triangle can test for movement of a triangle in a material zone 1022. A triangle moving through a material zone can be added to the table used to compute a polyhedron 1023. The loop for each triangle can continue until the last triangle has been tested 1024.

The matrix loop can continue to transform a triangles and edges array and run edge and triangle sub-loops for each matrix until a last matrix is reached 1025. When all matrices have been processed, the program can compute a polyhedron from information contained in a table into which the triangles have been stored 1026. Finally, a swept volume command program can come to an end 1027.

Proposed new Claim

1 (original – as filed) A software control method of modeling a swept volume for a computer simulated object comprising:
generating a polyhedral representation of a computer modeled object;
representing motion of the object with a set of position matrices
determining a subset of free neighborhood entities comprising the object for each matrix;
generating traces of the motion of the free neighborhood entities; and
constructing a representation of the swept volume from the traces.

1 (proposed) A software control method of modeling a swept volume for a computer simulated object comprising:
generating a polyhedral representation of a computer modeled object;
representing motion of the object with a set of position matrices
determining free neighborhood entities comprising a subset of the entities that form the object where the subset of entities are moving in their respective free neighborhoods as [entities comprising] the object moves between sequential ones of its positions in accordance with the position matrices [for each matrix];
generating traces of the motion of the free neighborhood entities; and
constructing a representation of the swept volume from the traces.